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RESEARCH ARTICLE

Forest fires in Southwest Bulgaria (2015–2024) in the context of national wildfire activity

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Abstract

Forest fires are an important driver of forest ecosystem dynamics in Bulgaria, and recent decades have been characterized by more frequent and sometimes extreme fire seasons. This study analyses wildfire activity in Southwest Bulgaria (Regional Forest Directorates Sofia, Blagoevgrad and Kyustendil) in the context of national patterns for the period 2015–2024, using official statistics from the Executive Forest Agency (EFA). Annual and cumulative indicators were calculated for the number of fires, burned forest and total affected area, seasonal distribution, vegetation types, ownership and reported causes and then related to average statistics for Bulgaria.

During the period 2015–2024, a total of 4,835 forest fires burned 62,320.9 ha of forest area in Bulgaria. In Southwest Bulgaria alone, 1,294 fires burned area 9,045.3 ha. The region accounts for 26.8% of the number of fires but only 14.5% of burned forest area, and shows a substantially smaller average forest area affected per fire (7.0 ha vs. 12.9 ha at the national level). Summer is the dominant fire season in terms of number of fires and burned area, but Southwest Bulgaria shows a relatively higher contribution of spring and winter fires. The year 2018 stands out as a typical "autumn-dominated" season, with more than 60% of all fires in Bulgaria and almost two thirds of those in the Southwest occurring in autumn. Broadleaved forests are most affected, and human activities (negligence and arson-caused fires) are the leading reported causes of ignition. The results indicate that Southwest Bulgaria has a specific fire regime, characterized by more frequent but generally smaller fires, and underline the need for regionally adapted fire risk assessment and prevention measures.

Keywords

wildfires; Southwest Bulgaria; fire regime; seasonality; fire risk; human-caused fires

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Introduction

Forest fires are a natural element of the dynamics of many forest ecosystems, but in recent decades their frequency, size and impact on society and the economy have significantly increased globally (Pausas, Keeley, 2019; Kelley et al., 2025). In Europe, extreme fire seasons have been recorded not only in the Mediterranean countries but also in more northern regions where large wildfires were historically rare. This raises questions about the adaptive capacity of forest ecosystems under changing climatic conditions and the effectiveness of fire prevention and risk management systems (EEA, 2021; El Garroussi et al., 2024; San-Miguel-Ayanz et al., 2024).

Within the European Union, Bulgaria contributes a relatively small share to the total burned area, yet forest fires have substantial implications for the condition and resilience of forest ecosystems at both national and regional scales. Several studies have analysed wildfire activity in Bulgaria at the national scale, focusing on fire frequency, burned area, seasonality and causes (Tsakov et al. 2004, 2019, 2021; Alexandrov 2020; Velichkova 2022; Velichkova et al. 2024). The historical development of forest fires also shows distinct changes in the fire regime over time. According to Alexandrov (2020), three main periods can be distinguished during the 20th century. The first covers the early decades up to the 1950s, when most fires affected only tens hectares. The second period, from the 1950s to about 1991, is characterized by lower fire frequency and relatively small burned areas, averaging around 1000 ha per year. The third period, after 1991, is marked by numerous large fires and a substantial increase in burned area. Large fires with around 27000 ha burned were already reported in 1903 in the Rhodopes, Rila and Pirin, and very severe seasons occurred again at the end of the 20th and the beginning of the 21st century, with more than 17000 ha burned in 1993, 14000 ha in 1994, over 57000 ha in 2000 and more than 40000 ha in 2007. These data clearly indicate that in the late 20th and early 21st century the fire regime in Bulgaria entered a new phase of increased activity and larger fire events.

In recent years, several studies based on remote sensing have analysed the spatial and temporal patterns of forest fires and post-fire forest recovery in Bulgaria (Stankova et al. 2023; Stoyanova 2024; Dobrinkova, Coskuner 2025). At the same time, various approaches and tools for wildfire risk assessment and mapping have been developed, including for protected areas and Natura 2000 forest sites (Roeva et al. 2020; Zoteva et al. 2021; Velichkova 2022; Borissova et al. 2024), as well as national risk assessment frameworks (Ministry of Interior 2021). Together, these studies situate national fire dynamics within a broader context, relating them to climatic drivers, land use patterns and risk management measures. However, most of the available literature treats Bulgaria as a single homogeneous unit, whereas regional variations in fire regime remain comparatively less studied and are rarely quantified.

Southwest Bulgaria represents a relevant case study region in this context. The region comprises the territories of the Regional Forest Directorates (RFDs) Sofia, Blagoevgrad and Kyustendil and is characterized by complex topography, transitional continental-Mediterranean climatic influence and a mosaic of forest types – from

low-elevation oak and thermophilous deciduous forests to high-mountain coniferous stands of Scots pine and black pine (EFA, 2011; Peneva et al., 2023). This combination of natural and anthropogenic factors suggests a specific fire regime that may differ from national averages.

Official statistics from the Executive Forest Agency (EFA) show that during 2015–2024 Southwest Bulgaria accounted for a substantial share of all forest fires in the country, but a comparatively smaller proportion of the burned forest area. This suggests a prevalence of more frequent but relatively smaller fire events, which is important for planning prevention, organizing suppression and assessing risk for different forest types and ownership categories. At the same time, we are not aware of previous publications that systematically analyse this regional pattern and quantify its difference from the national situation.

Additional complexity arises from the limitations of the available data. The national fire database of EFA is administrative in nature and does not include information on fire intensity or duration, nor systematic assessment of ecological and economic damage. A considerable proportion of fires are reported with "unknown cause", and the lack of comparable damage estimates restricts the possibility to link fire activity directly to impacts on ecosystem services and local communities. This underlines the need for careful interpretation of purely statistical results and for combining quantitative and qualitative approaches.

Against this background, the aim of the present study is to characterize wildfire activity in Southwest Bulgaria for the period 2015–2024 in the context of national wildfire dynamics, using official EFA data. Specifically, we analyse fire frequency, burned area, seasonality, distribution by vegetation type, ownership and reported causes, as well as the ratio between surface and crown fires. By comparing Southwest Bulgaria directly with Bulgaria as a whole, we seek to identify regional features of the fire regime that are relevant for fire risk assessment and the planning of prevention and management measures.

Material and Methods

Study area

The study covers Southwest Bulgaria, defined as the combined territories of the three Regional Forest Directorates (RFDs) Sofia, Blagoevgrad and Kyustendil. According to the Executive Forest Agency's (EFA) Geo-information Portal (maps.iag.bg; data as of 31 December 2023), forests managed by the State Forest Enterprises (SFE) and State Hunting Enterprises (SHE) within these three RFDs cover 1,023,271 ha, accounting for 26.8% of Bulgaria's state forest territory. The region includes parts of Sredna Gora, western Stara Planina, Rila, Pirin, Vitosha and the Osogovo–Belasitsa mountain system, as well as inter-mountain basins and lowlands. The climate is transitional between temperate-continental and continental-Mediterranean, with pronounced warm and dry summer months that favour the occurrence and spread of forest fires.

Forest ecosystems are highly heterogeneous and species-rich, ranging from low-elevation oak and thermophilous deciduous stands, through beech and mixed broadleaved forests, to high-elevation coniferous stands dominated by black pine (*Pinus nigra*) and Scots pine (*Pinus sylvestris*). The region also includes a notable share of artificial (planted) coniferous forests, particularly pine plantations established for afforestation and erosion-control purposes. Compared to native broadleaved stands, such planted coniferous forests may present more homogeneous and continuous fuels, which can increase susceptibility to ignition and promote faster fire spread under dry and windy conditions, however, this potential effect was not quantified in the present study. The location and extent of the study region are illustrated in Fig. 1.

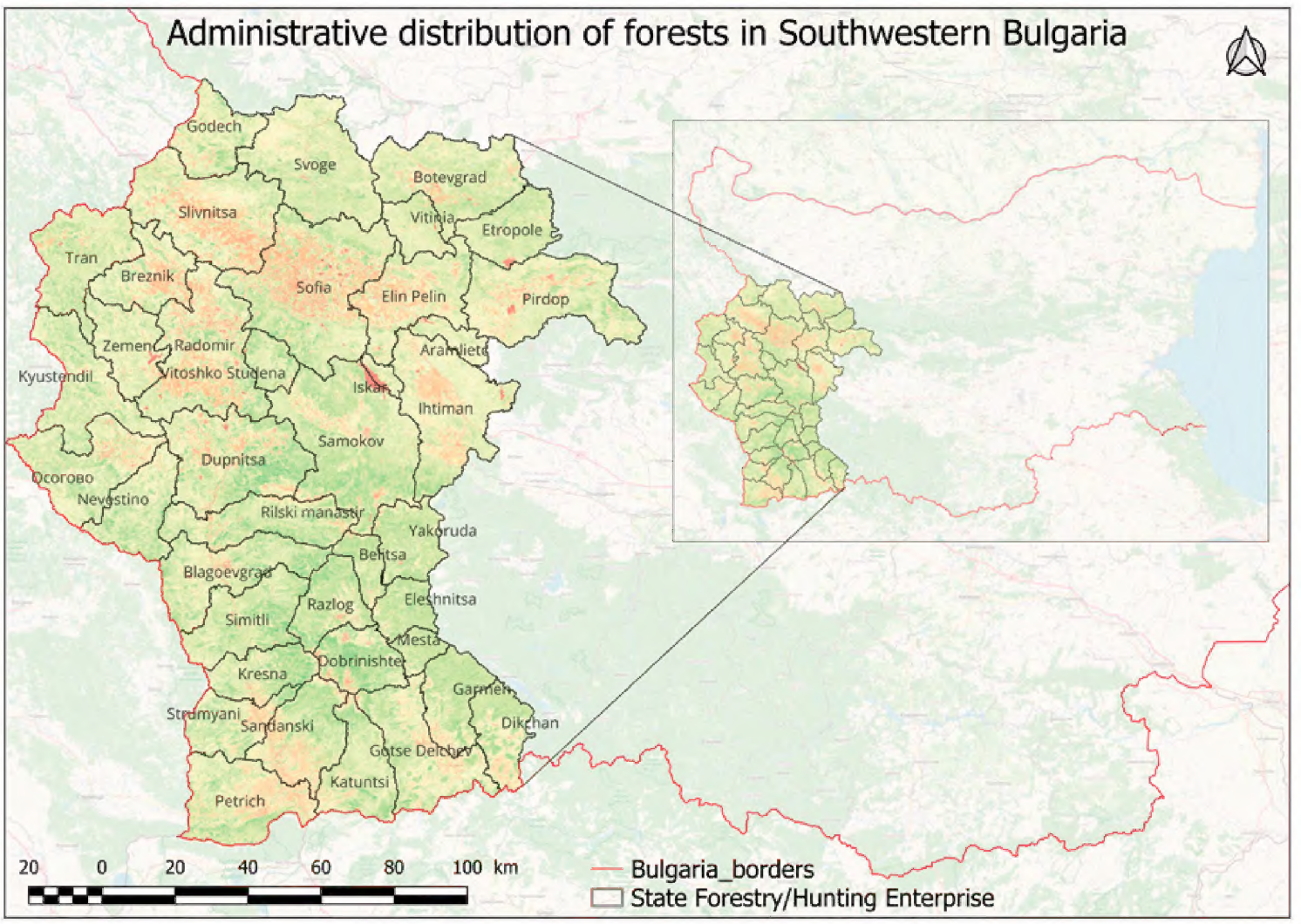

Fig. 1. Geographical location and administrative distribution of forests in Southwest Bulgaria (map is author's own creation).

Data source and preprocessing

The analysis is based on official statistics of the Executive Forest Agency of Bulgaria for the period 2015–2024. We use annual data for all recorded forest fires in the country, structured by RFD. The database contains, for each fire, information on the date of occurrence, burned area by land category, season of occurrence, vegetation type, ownership category, reported cause of ignition and fire type (surface or

crown). For the purposes of this study, Bulgaria is represented by the sum over all RFDs, and Southwest Bulgaria by the combined data for RFD Sofia, Blagoevgrad and Kyustendil.

In a first step, the data were checked and standardized to ensure consistency across years and regions. The basic temporal unit of analysis is the calendar year. Burned forest area refers to forest territories as defined by the Forest Act; total burned area additionally includes other land categories within forest territories (shrublands, grasslands, unstocked forest lands, etc.).

Indicators and classification

Several groups of indicators were calculated. At national and regional level, we derived the annual number of fires, burned forest area and total burned area. We also calculated mean forest area per fire and mean total area per fire, the relative share of Southwest Bulgaria in the total number of fires and in burned forest area for the country, and the seasonal distribution of fires and burned forest area.

Seasons were defined on a calendar basis as follows: winter (December–February), spring (March–May), summer (June–August) and autumn (September–November). The seasonal analysis focuses primarily on the number of fires per season; where possible, we also comment on the seasonal distribution of burned forest area.

Additional structural indicators include the share of burned area by vegetation type (broadleaved, coniferous, mixed forests and other burnable areas such as shrubs and grasslands), ownership (state, municipal, private, church forests and forests owned by legal entities) and fire type (surface vs. crown fires). Causes of ignition are grouped into several main categories: negligence, arson, natural causes (mainly lightning) and unknown or unclear causes.

Statistical analysis

The statistical analysis is based primarily on descriptive statistics and comparative analysis between Southwest Bulgaria and the country as a whole. For each year we calculated means, ranges and relative shares of key indicators. Annual dynamics in the number of fires and burned forest area were examined using the aggregated values for the period 2015–2024, summarized in Table 2, while the main integral indicators for the entire period are presented in Table 1. For selected indicators we calculated linear correlation coefficients between Southwest Bulgaria and Bulgaria, to assess the extent to which the regional dynamics follows the national pattern. The seasonal distribution of the number of forest fires in Bulgaria and Southwest Bulgaria is visualized in Fig. 2.

All calculations and graphical outputs were produced in Microsoft Excel. Where necessary, the results were checked and additional aggregations were performed in R or Python, for example, for computing correlation coefficients or verifying aggregated values.

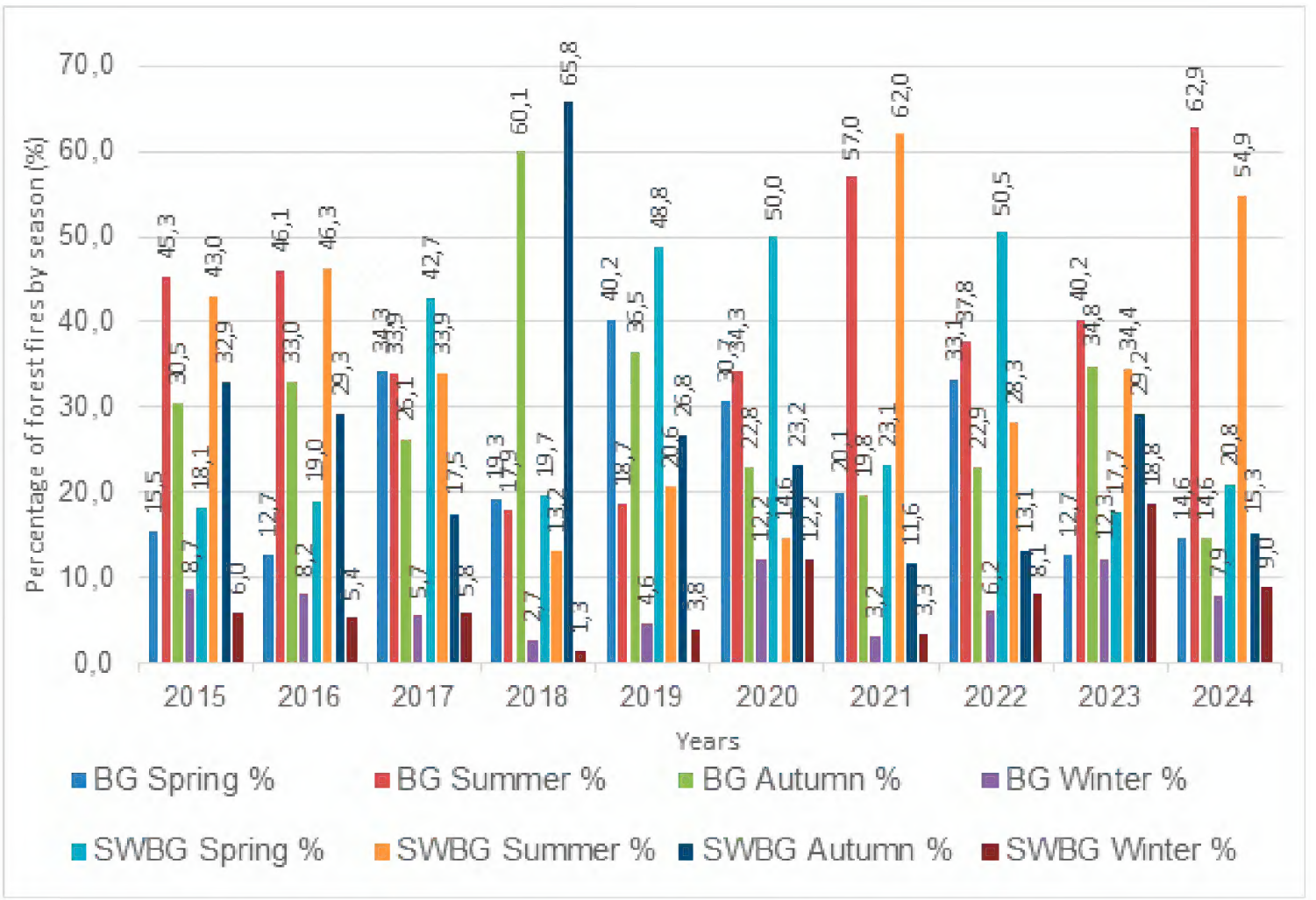

Fig. 2. Seasonal distribution of the number of forest fires in Bulgaria and Southwest Bulgaria for the period 2015–2024 (winter: XII–II; spring: III–V; summer: VI–VIII; autumn: IX–XI).

* Abbreviations: BG – Bulgaria; SWBG – Southwest Bulgaria.

Results

Overall fire activity in Bulgaria and Southwest Bulgaria

During 2015–2024 a total of 4835 forest fires were recorded in Bulgaria, burning 62 320.9 ha of forest area and 107 277.9 ha of total area within forest territories. In the same period, 1294 forest fires were recorded in Southwest Bulgaria, with 9045.3 ha of burned forest area and 14 190.4 ha of total burned area. Thus, Southwest Bulgaria accounts for 26.8% of all forest fires but only 14.5% of burned forest area and 13.2% of total burned area in the country (Table 1).

The mean forest area per fire in Bulgaria for the ten-year period is 12.9 ha, while in Southwest Bulgaria it is almost half of this value (7.0 ha). The mean total burned area per fire is 22.2 ha nationally and 11.0 ha in Southwest Bulgaria. These differences indicate that, on average, fires in Southwest Bulgaria are smaller in size than the national average, despite the relatively high fire frequency.

Inter-annual variability is pronounced. Some years are characterized by relatively low burned area (e.g. 2018), while others show markedly higher values (notably 2022 and 2024). The annual number of fires also fluctuates, but less dramatically than burned area, suggesting that the size distribution of fires, especially the occurrence of large events, plays a major role in the inter-annual variation of burned area.

Table 1. Main indicators of fire activity in Bulgaria and Southwest Bulgaria for the period 2015–2024.

Indicator	Bulgaria	Southwest Bulgaria
Number of wildfires (no.)	4835	1294
Burned forest area (ha)	62 320.9	9045.3
Total burned area (ha)	107 277.9	14 190.4
Average forest area per fire (ha)	12.9	7
Average total area per fire (ha)	22.2	11

Burned forest area and total burned area

In Bulgaria the total burned forest area during 2015–2024 is almost 4.5 times larger than the corresponding value for Southwest Bulgaria, while the number of fires is less than four times larger. This results in a higher mean fire size at the national scale. The ratio between burned forest area and total burned area is similar in both cases: forest accounts for about 58% of total burned area in Bulgaria and about 64% in Southwest Bulgaria. This indicates that a considerable share of fire activity affects non-forest land within forest territories (shrubs, grasslands, unstocked forest lands).

The annual data (Table 2) show that the largest burned forest areas in Bulgaria occur in 2022 and 2024, both years being associated with particularly severe fire seasons in several regions of the country. In Southwest Bulgaria, the peak years in terms of burned forest area are also 2022 and 2024, but the absolute values remain much lower than the national totals.

Table 2. Annual indicators (2015–2024) for Bulgaria and Southwest Bulgaria.

Year	BG* All Fires	SWBG All Fires	BG Forest Area (ha)	SWBG Forest Area (ha)	BG Total Area (ha)	SWBG Total Area (ha)	SWBG share All Fires (%)	SWBG share Forest Area (%)	SWBG share Total Area (%)
2015	439	149	4315	1140.4	5471.8	1736.4	33.94	26.43	31.73
2016	584	147	6340.2	252.5	17 569.4	546.6	25.17	3.98	3.11
2017	513	171	4569.4	2093.8	6630.1	2620.3	33.33	45.82	39.52
2018	223	76	1453	149.9	1582.5	180.5	34.08	10.32	11.41
2019	669	209	5611.3	767.3	8638.4	1593.2	31.25	13.67	18.44
2020	499	82	5257.9	350.6	10 416.1	469.7	16.43	6.67	4.51
2021	349	121	3143.4	1073.9	4773.5	1625.8	34.67	34.16	34.06
2022	516	99	8126	372.1	10 718.4	475.8	19.19	4.58	4.44
2023	448	96	6388.3	415.4	8956.4	862.8	21.43	6.5	9.63
2024	595	144	17 116.4	2429.4	32 521.3	4079.3	24.2	14.19	12.54

* Abbreviations: BG – Bulgaria; SWBG – Southwest Bulgaria.

Vegetation types, ownership and fire type

Broadleaved forests are the most affected vegetation type in both Bulgaria and Southwest Bulgaria, followed by coniferous forests and mixed stands. This largely reflects the overall forest composition, but also the fact that many fires start in or spread through low-elevation broadleaved stands and shrublands.

In terms of ownership, state forests account for the largest share of burned forest area, followed by municipal and private forests. The relative share of municipal and private forests in the burned area in Southwest Bulgaria is somewhat higher than at the national scale, which is consistent with the higher fragmentation and mixed ownership structure in parts of the region.

Surface fires dominate in both Bulgaria and Southwest Bulgaria, accounting for the vast majority of recorded events. Crown fires are comparatively rare but are associated with some of the largest burned areas in coniferous forests, especially in years with extreme fire weather conditions.

Seasonal distribution of forest fires

At the national level, summer is the dominant fire season both in terms of the number of fires and total burned area. Over the period 2015–2024, approximately 53.3% of all recorded fires in Bulgaria occur in summer, and the corresponding share of burned forest area reaches about 71%. Spring and autumn each account for around 14–15% of the number of fires, while winter accounts for about 17%. In Southwest Bulgaria, summer remains the season with the highest number of fires in absolute terms, but the relative contribution of spring and winter fires is higher than at the national level, which effectively extends the period of elevated fire risk.

The year 2018 stands out as a distinct atypical season. In 2018 only 17.9% of all forest fires in Bulgaria wererecorded in summer, whereas 60.1% occur in autumn. The pattern is even more pronounced in Southwest Bulgaria, where only 13.2% of fires occur in summer and 65.8% in autumn. Thus, 2018 is the most "autumn-dominated" year in the entire study period and illustrates that, in certain years, the peak of fire activity can shift markedly towards the end of the vegetation season.

Reported causes of ignition

In both Bulgaria and Southwest Bulgaria, the majority of fires are attributed to human causes. Negligence (careless use of fire, uncontrolled burning of agricultural residues, etc.) is the leading reported cause, followed by arson-caused fires. Fires caused by natural factors, primarily lightning, represent only a small fraction of all recorded events. A considerable proportion of fires, however, are reported with unknown or unclear cause, which limits the possibility for detailed analysis of ignition patterns and for targeting prevention measures to specific risk behaviours.

Discussion

The results of this study confirm that forest fires in Bulgaria during 2015–2024 are highly variable in time, with some years characterized by relatively mild fire seasons and others by large burned areas and numerous events. Southwest Bulgaria emerges as a region with a distinct fire regime: it concentrates more than a quarter of all recorded forest fires in the country, yet accounts for only about 15% of the burned forest area. This pattern of more frequent but generally smaller fires can be regarded as a region-specific fire regime that differs from the typical Mediterranean pattern characterized by fewer but larger fires.

Several factors may contribute to this regional specificity. The complex topography and mosaic of vegetation and land use in Southwest Bulgaria can limit the spread of some fires and favour the occurrence of multiple small events rather than single large ones. At the same time, the transitional Continental–Mediterranean climate and the high human pressure in many parts of the region (settlements, infrastructure, agriculture, tourism) create numerous ignition opportunities, especially during dry and windy periods. The higher relative contribution of spring and winter fires in Southwest Bulgaria compared to the national averages also suggests that the period of elevated fire risk in the region is extended beyond the "classic" summer season.

The seasonal analysis indicates that 2018 differs markedly from the remaining years in the study period. This year is atypical not only due to the lowest burned forest area in the study period, but also due to a seasonal distribution strongly shifted towards autumn, both in Bulgaria as a whole and in Southwest Bulgaria. More than 60% of all fires in the country, and almost two thirds in Southwest Bulgaria, are recorded in autumn, while the summer share remains below 20%. Such a shift of the fire peak towards the end of the vegetation season is likely related to a specific combination of meteorological conditions (for example relatively moist or cool conditions in early summer and warmer, drier conditions during late summer and autumn), as described in regional climate analyses for 2018. In the present study, however, we do not perform quantitative modelling of the relationships between climate variables and fire activity, and this interpretation should therefore be regarded as a working hypothesis rather than a formally tested conclusion. Regardless of the specific causes, such "autumn-dominated" years emphasize that fire prevention and preparedness systems should not focus solely on the summer months but should cover a wider period of the year, including autumn, particularly in regions such as Southwest Bulgaria.

The dominance of broadleaved forests in the burned area reflects both their large overall share in the forest cover and the fact that many ignitions occur at low and middle elevations close to the wildland–urban interface and agricultural lands. The relatively higher share of municipal and private forests in the burned area of Southwest Bulgaria compared to national averages may be related to differences in management capacity, accessibility and fuel continuity, and deserves further investigation.

The high proportion of fires attributed to negligence and arson confirms the central role of human activities as drivers of wildfire risk in Bulgaria. At the same time, the large share of fires stemming from unknown or unclear causes demonstrates

limitations in the reporting and investigation process. Improved investigation of fire causes and better documentation would allow more targeted prevention campaigns and more precise allocation of resources for risk reduction.

Finally, the limitations of the EFA database must be considered when interpreting the results. The administrative nature of the data, the lack of consistent information on fire intensity and duration, and the absence of standardized estimates of ecological and economic damage constrain the analysis to frequency and area-based indicators. Future work should aim to integrate administrative statistics with remote sensing products and field-based assessments of post-fire effects, as well as with meteorological and fuel-related data, in order to support more comprehensive fire risk models and management strategies.

Conclusions

Wildfire activity in Bulgaria during 2015–2024 is highly variable, with individual years showing very large burned areas (especially 2022 and 2024), which is consistent with the tendency towards more extreme fire seasons in the early 21st century.

Southwest Bulgaria stands out as a region with high fire frequency but comparatively small mean fire size: it accounts for about 27% of all forest fires in the country, but only about 15% of the burned forest area. This indicates a fire regime dominated by more frequent but generally smaller events.

Summer is the dominant fire season at both national and regional level, but in Southwest Bulgaria spring and winter fires play a relatively more important role, effectively extending the period of elevated fire risk. The year 2018 is an atypical "autumn-dominated" season, illustrating that the seasonal pattern of fire activity is not stable and may shift substantially in some years.

Human activities, particularly negligence and arson, are the leading reported causes of ignition, while the substantial share of fires stemming from unknown causes highlights the need for improved investigation and documentation. These findings underline the importance of regionally adapted fire prevention and preparedness measures that take into account the specific fire regime of Southwest Bulgaria.

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